vibration of the earth's crust. My brother Horace and I were, we believe, the first to verify in England the observations of Bertelli, Rossi, d'Abbadie, and the other (principally Italian) pioneers in this interesting subject.

In our Reports to the British Association for 1881 and 1882 on "The Lunar Disturbance of Gravity," some account will be found of the earlier literature on the subject.

January 9. G. H. DARWIN.

Meteor.

ON Sunday, 12th inst., about 8.10 p.m., a bright meteor was seen here, coming into view near δ Aurigæ. It was of a reddish colour, moved slowly, leaving a short tail, and burst above ε Leonis, then with diminished light continued its course to the horizon. T. W. MORTON.

Beaumont College, Old Windsor, January 13.

MAGNETISM.[1]

I.

AS old as any part of electrical science is the knowledge that a needle or bar of steel which has been touched with a loadstone will point to the north. Long before the first experiments of Galvani and Volta the general properties of steel magnets had been observed—how like poles repelled each other, and unlike attracted each other; how the parts of a broken magnet were each complete magnets with a pair of poles. The general character of the earth's magnetism has long been known—that the earth behaves with regard to magnets as though it had two magnetic poles respectively near the rotative poles, and that these poles have a slow secular motion. For many years the earth's magnetism has been the subject of careful study by the most powerful minds. Gauss organized a staff of voluntary observers, and applied his unsurpassed powers of mathematical analysis to obtaining from their results all that could be learned.

The magnetism of iron ships is of so much importance in navigation that a good deal of the time of men of great power has been devoted to its study. It was *the* scientific study of Archibald Smith; and Airy and Thomson have added not a little to our practical knowledge of the disturbance of the compass by the iron of the ship. Sir W. Thomson, in addition to much valuable practical work on the compass, and experimental work on magnetism, has given the most complete and elegant mathematical theory of the subject. Of late years the development of the dynamo machine has directed attention to the magnetization of iron from a different point of view, and a very great deal has been done by many workers to ascertain the facts regarding the magnetic properties of iron. The upshot of these many years of study by practical men interested in the mariner's compass or in dynamo machines by theoretical men interested in looking into the nature of things, is, that although we know a great many facts about magnetism, and a great deal about the relation of these facts to each other, we are as ignorant as ever we were as to any reason why the earth is a magnet, as to why its magnetic poles are in slow motion in relation to its substance, or as to why iron, nickel, and cobalt are magnetic, and nothing else, so far as we know, is to any practical extent. In most branches of science the more facts we know the more fully we recognize a continuity in virtue of which we see the same property running through all the various forms of matter. It is not so in magnetism; here the more we know the more remarkably exceptional does the property appear, the less chance does there seem to be of resolving it into anything else. It seems to me that I cannot better occupy the present occasion than by recalling your attention to, and inviting discussion of, some of those salient properties of magnetism as exhibited by iron, nickel, and cobalt—properties most of them very familiar, but properties which any theory of magnetism must reckon with and explain. We shall not touch on the great subject of the earth as a magnet—though much has been recently done, particularly by Rücker and Thorpe—but deal simply with magnetism as a property of these three bodies, and consider its natural history, and how it varies with the varying condition of the material.

To fix our ideas, let us consider, then, a ring of uniform section of any convenient area and diameter. Let us suppose this ring to be wound with copper wire, the convolutions being insulated. Over the copper wire let us suppose that a second wire is wound, also insulated, the coils of each wire being arranged as are the coils of any ordinary modern transformer. Let us suppose that the ends of the inner coil, which we will call the secondary coil, are connected to a ballistic galvanometer; and that the ends of the outer coil, called the primary, are connected, through a key for reversing the current, with a battery. If the current in the primary coil is reversed, the galvanometer needle is observed to receive a sudden or impulsive deflection, indicating that for a short time an electromotive force has been acting on the secondary coil. If the resistance of the secondary circuit is varied, the sudden deflection of the galvanometer needle varies inversely as the resistance. With constant resistance of the secondary circuit the deflection varies as the number of convolutions in the secondary circuit. If the ring upon which the coils of copper wire are wound is made of wood or glass—or, indeed, of 99 out of every 100 substances which could be proposed—we should find that for a given current in the primary coil the deflection of the galvanometer in the secondary circuit is substantially the same. The ring may be of copper, of gold, of wood, or glass—it may be solid or it may be hollow—it makes no difference in the deflection of the galvanometer. We find, further, that with the vast majority of substances the deflection of the galvanometer in the secondary circuit is proportional to the current in the primary circuit. If, however, the ring be of soft iron, we find that the conditions are enormously different. In the first place, the deflections of the galvanometer are very many times as great as if the ring were made of glass, or copper, or wood. In the second place, the deflections on the galvanometer in the secondary circuit are not proportional to the current in the primary circuit; but as the current in the primary circuit is step by step increased we find that the galvanometer deflections increase somewhat, as is illustrated in the accompanying curve (Fig. 1), in which the abscissæ are proportional to the primary current, and the ordinates are proportional to the galvanometer deflections. You observe that as the primary current is increased the galvanometer deflection increases at first at a certain rate; as the primary current attains a certain value the rate at which the deflection increases therewith is rapidly increased, as shown in the upward turn of the curve. This rate of increase is maintained for a time, but only for a time. When the primary current attains a certain value the curve bends downward, indicating that the deflections of the galvanometer are now increasing less rapidly as the primary current is increased; if the primary current be still continually increased, the galvanometer deflections increase less and less rapidly.

Now what I want to particularly impress upon you is the enormous difference which exists between soft iron on the one hand, and ordinary substances on the other. On this diagram I have taken the galvanometer deflections to the same scale for iron, and for such substances as glass or wood. You see that the deflections in the case of glass or wood, to the same scale, are so small as to be absolutely inappreciable, whilst the deflection for iron at one point of the curve is something like 2000 times as great as for non-magnetic substances. This extraordinary property is possessed by only two other substances besides iron—cobalt and nickel. On the same figure are curves showing on the same scale what would be the deflections for cobalt and nickel, taken from Prof. Rowlands's paper. You observe that they show the same general characteristics as iron, but in a rather less degree. Still, it is obvious that these substances may be broadly classed with iron in contradistinction to the great mass of other bodies. On the other hand, diamagnetic bodies belong distinctly to the other class. If the deflection with a non-magnetic ring be unity, that with iron, as already stated, may be as much as 2000; that with bismuth, the most powerful diamagnetic known, is 0·999825—a quantity differing very little from unity. Note, then, the first fact which any theory of magnetism has to explain is: Iron, nickel, and cobalt, all enormously magnetic; other substances practically non-magnetic. A second fact is: With most bodies the action of the primary current on the secondary circuit is strictly proportional to the primary current; with magnetic bodies it is by no means so.

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[1] Inaugural Address delivered before the Institution of Electrical Engineers, on Thursday, January 9, by J. Hopkinson, M.A., D.Sc., F.R.S., President.

You will observe that the ordinates in these curves, which are proportional to the kicks or elongations of the galvanometer, are called induction, and that the abscissæ are called magnetizing force. Let us see a little more precisely what we mean by the terms, and what are the units of measurement taken. The elongation of the galvanometer measures an impulsive electromotive force—an electromotive force acting for a very short time. Charge a condenser to a known potential, and discharge it through the galvanometer: the needle of the galvanometer will swing aside through a number of divisions proportional to the quantity of electricity in the condenser—that is, to the capacity and the potential. From this we may calculate the quantity of electricity required to give a unit elongation. Multiply this by the actual resistance of the secondary circuit and we have the impulsive electromotive force in volts and seconds, which will, in the particular secondary circuit, give a unit elongation. We must multiply this by 10^8 to have it in absolute C.G.S. units. Now the induction is the impulsive electromotive force in absolute C.G.S. units divided by the number of secondary coils and by the area of section of the ring in square centimetres. The line integral of magnetizing force is the current in the primary in absolute C.G.S. units—that is, one-tenth of the current in amperes—multiplied by 4π. The magnetizing force is the line integral divided by the length of the line over which that line integral is distributed. This is, in truth, not exactly the same for all points of the section of the ring—an imperfection so far as it goes in the ring method of experiment. The absolute electro-magnetic C.G.S. units have been so chosen that if the ring be perfectly non-magnetic the induction is equal to the magnetizing force. We may refer later to the permeability, as Sir W. Thomson calls it; it is the ratio of the induction to the magnetizing force causing it, and is usually denoted by μ.

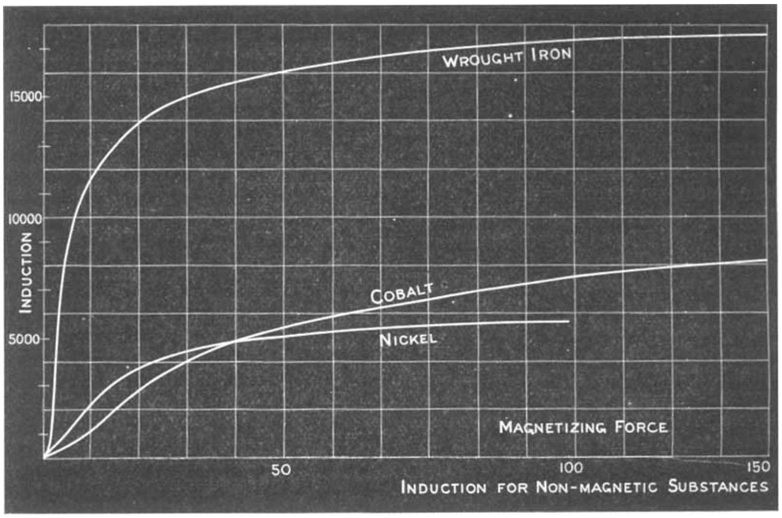

FIG. 1.

There is a further difference between the limited class of magnetic bodies and the great class which are non-magnetic. To show this, we may suppose our experiment with the ring to be varied in one or other of two or three different ways. To fix our ideas, let us suppose that the secondary coil is collected in one part of the ring, which, provided that the number of turns in the secondary is maintained the same, will make no difference in the result in the galvanometer. Let us suppose, further, that the ring is divided so that its parts may be plucked from together, and the secondary coil entirely withdrawn from the ring. If now the primary current have a certain value, and if the ring be plucked apart and the secondary coil withdrawn, we shall find that, whatever be the substance of which the ring is composed, the galvanometer deflection is one-half of what it would have been if the primary current had been reversed. I should perhaps say approximately one-half, as it is not quite strictly the case in some samples of steel, although, broadly speaking, it is one-half. This is natural enough, for the exciting cause is reduced from—let us call it a positive value, to nothing when the secondary coil is withdrawn; it is changed from a positive value to an equal and opposite negative value when the primary current is reversed. Now comes the third characteristic difference between the magnetic bodies and the non-magnetic. Suppose that, instead of plucking the ring apart when the current had a certain value, the current was raised to this value and then gradually diminished to nothing, and that then the ring was plucked apart and the secondary coil withdrawn. If the ring be non-magnetic, we find that there is no deflection of the galvanometer; but, on the other hand, if the ring be of iron, we find a very large deflection, amounting, it may be, to 80 or 90 per cent. of the deflection caused by the withdrawal of the coil when the current had its full value. Whatever be the property that the passing of the primary current has imparted to the iron, it is clear that the iron retains a large part of this property after the current has ceased. We may push the experiment a stage further. Suppose that the current in the primary is raised to a great value, and is then slowly diminished to a smaller value, and that the ring is opened and the secondary coil withdrawn. With most substances we find that the galvanometer deflection is precisely the same as if the current had been simply raised to its final value. It is not so with iron: the galvanometer deflection depends not alone upon the current at the moment of withdrawal, but on the current to which the ring has been previously subjected. We may then draw another curve (Fig. 2) representing the galvanometer deflections produced when the current has been raised to a high value and has been subsequently reduced to a value indicated by the abscissæ. This curve may be properly called a descending curve. In the case of ordinary bodies this curve is a straight line coincident with the straight line of the ascending curve, but for iron is a curve such as is represented in the drawing. You observe that this curve descends to nothing like zero when the current is reduced to zero; and that when the current is not only diminished to zero, but is reversed, the galvanometer deflection only becomes zero when the reversed current has a substantial value. This property possessed by magnetic bodies of retaining that which is impressed upon them by the primary current has been called by Prof. Ewing "hysteresis," or, as similar properties have been observed in quite other connections, "magnetic hysteresis." The name is a good one, and has been adopted. Broadly speaking, the induction as measured by the galvanometer deflection is independent of the time during which the successive currents have acted, and depends only upon their magnitude and order of succession. Some recent experiments of Prof. Ewing, however, seem to show a well-marked time effect. There are curious features in these experiments which require more elucidation.

It has been pointed out by Warburg, and subsequently by Ewing, that the area of curve 2 is a measure of the quantity of energy expended in changing the magnetism of the mass of iron from that produced by the current in one direction to that produced by the current in the opposite direction and back again. The energy expended with varying amplitude of magnetizing forces has been determined for iron, and also for large magnetizing forces for a considerable variety of samples of steel. Different sorts of iron and steel differ from each other very greatly in this respect. For example, the energy lost in a complete cycle of reversals in a sample of Whitworth's mild steel was about 10,000 ergs per cubic centimetre; in oil-hardened hard steel it was near 100,000; and in tungsten steel it was near 200,000—a range of variation of 20 to 1. It is, of course, of the greatest possible importance to keep this quantity low in the case of armatures of dynamos, and in that of the cores of transformers. If the armature of a dynamo machine be made of good iron, the loss from hysteresis may easily be less than 1 per cent.; if, however, to take an extreme case, it were made of tungsten steel, it would readily amount to 20 per cent. In the case of transformers and alternate-current dynamo machines, where the number of reversals per second is great, the loss of power by hysteresis of the iron, and the consequent heating, become very important. The loss of power by hysteresis increases more rapidly than does the induction. Hence it is not well in such machines to work the iron to anything like the same intensity of induction as is desirable in ordinary continuous current machines. The quantity O A, when measured in proper units, as already explained—that is to say, the reversed magnetic force, which just suffices to reduce the induction as measured by the kick on the galvanometer to nothing after the material has been submitted to a very great magnetizing force—is called the "coercive force," giving a definite meaning to a term which has long been used in a somewhat indefinite sense. The quantity is really the important one in judging the magnetism of short permanent magnets. The residual magnetism, O B, is then practically of no interest at all; the magnetic moment depends almost entirely upon the coercive force. The range of magnitude is somewhat greater than in the case of the energy dissipated in a complete reversal. For very soft iron the coercive force is 1·6 C.G.S. units; for tungsten steel, the most suitable material for magnets, it is 51 in the same units. A very good guess may be made of the amount of coercive force in a sample of iron or steel by the form of the ascending curve, determined as I described at first. This is readily seen by inspection of Fig. 3, which shows the curves in the cases of wrought iron, and steel containing 0·9 per cent. of carbon. With the wrought iron a rapid ascent of the ascending curve is made, when the magnetizing force is small and the coercive force is small; in the case of the hard steel the ascent of the curve is made with a larger magnetizing current, and the coercive force is large. There is one curious feature shown in the curve for hard steel which may, so far as I know, be observed in all magnetizable substances: the ascending curve twice cuts the descending curve, as at M and N. This peculiarity was, so far as I know, first observed by Prof. G. Wiedemann.

I have already called emphatic attention to the fact that magnetic substances are enormously magnetic, and that non-magnetic substances are hardly at all magnetic:

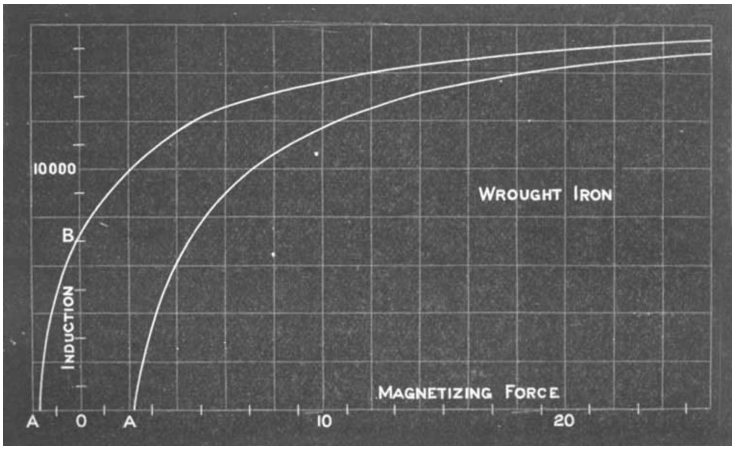

FIG. 2.

there is between the two classes no intermediate class. The magnetic property of iron is exceedingly easily destroyed. If iron be alloyed with 12 per cent. of manganese, the kick on the galvanometer which the material will give, if made into a ring, is only about 25 per cent. greater than is the case with the most completely non-magnetic material, instead of being some hundreds of times as great, as would be the case with iron. Further, with this manganese steel, the kick on the galvanometer is strictly proportional to the magnetizing current in the primary, and the material shows no sign of hysteresis. In short, all its properties would be fully accounted for if we supposed that manganese steel consisted of a perfectly non-magnetic material, with a small percentage of metallic iron mechanically admixed therewith. Thus the property of non-magnetizability of manganese steel is an excellent proof of the fact—which is also shown by the non-magnetic properties of most compounds of iron—that the property appertains to the molecule, and not to the atom; or to put it in another way, suppose that we were to imagine manganese steel broken up into small particles, as these particles became smaller there would at length arrive a point at which the iron and the manganese would be entirely separated from each other: when this point is reached the particles of iron are non-magnetic. By the magnetic molecule of the substance we mean the smallest part which has all the magnetic properties of the mass. The magnetic molecule must be big enough to contain its proportion of manganese. In iron, then, we must have a collection of particles of such magnitude that it would be possible for the manganese to enter into each of them, to constitute an element of the magnet. Manganese is, so far as I know, a non-magnetic element. Smaller proportions of manganese reduce the magnetic property in a somewhat less degree, the reduction being greater as the quantity of manganese is greater. It appeared very possible that the non-magnetic property of manganese steel was due to the coercive force being very great—that, in fact, in all experiments we were still on that part of the magnetization curve below the rapid rise, and that if the steel were submitted to greater forces it would presently prove to be magnetic, like other kinds of steel. Prof. Ewing, however, has submitted manganese steel to very great forces indeed, and finds that its magnetism is always proportional to the magnetizing force.

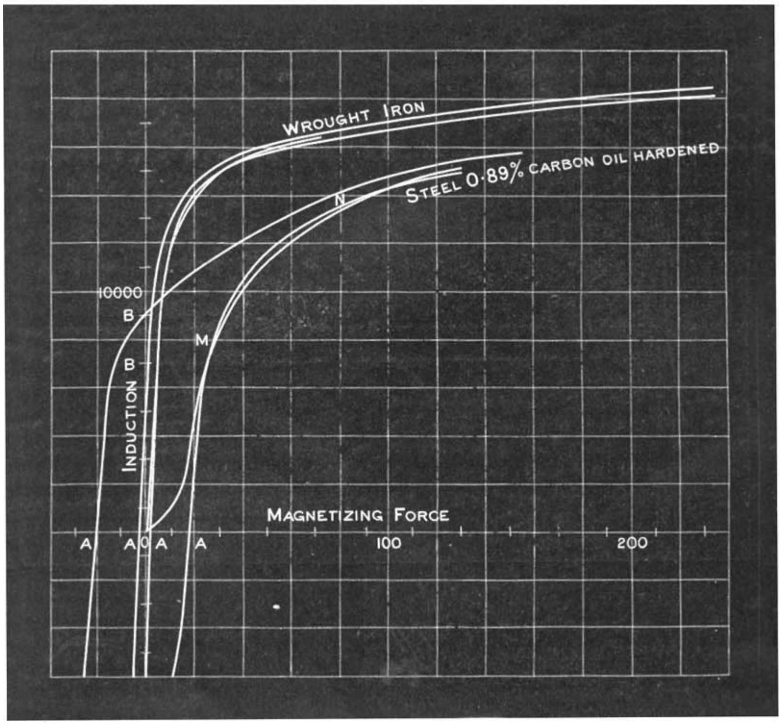

FIG. 3

No single body is known having the property of capacity for magnetism in a degree which is neither very great nor very small, but intermediate between the two extremes. We can, however, mix magnetic and non-magnetic substances to form bodies apparently intermediate. It is, therefore, interesting to consider what the properties might be of such a mixture. It depends quite as much on the way in which the magnetic part is arranged in the mass, as on its actual quantity. Suppose, for example, it is arranged as in Fig. 4—in threads or plates having a very long axis in the direction of the magnetizing force—we may at once determine the curve of magnetization of the mixture from that of the magnetic substance by dividing the induction for any given force in the ratio of the whole volume to the volume of magnetic substance. If, on the other hand, it is as in Fig. 5—with a very short axis in the direction of the force, and a long axis perpendicular thereto—we can equally construct the curve of magnetization. This is done in Fig. 6, which shows the curve when nine-tenths of the material is highly magnetic iron, arranged as in Fig. 5, whilst the other curve of the same figure is that when only one-tenth is magnetic, but arranged as in Fig. 4. You observe how very different is the character of the curve—a difference which is reduced by the much less proportion of magnetic material in the mixture in the one case than in the other. One peculiarity of these arrangements of the two materials in relation to each other is, that the resulting material is not isotropic; that is, its properties are not the same in all directions, but depend upon the direction of the magnetizing force in the material. Of course, this is not at all a probable arrangement but it is instructive in showing the character of the result as depending upon the construction of the material. Let us, however, consider the simplest isotropic arrangement; let us suppose that one material is in the form of spheres bedded in a matrix of the other: if the spheres are placed at random this is clearly an isotropic arrangement. The result is very different according as the matrix or the spheres are of the magnetic material. Suppose that the volume of the spheres is one-half of the whole volume. In Fig. 7 we have approximately the curve for iron, for a mixture of equal quantities of iron and a non-magnetic material; the spheres being non-magnetic and the matrix iron, and for a mixture, the spheres being iron and the matrix non-magnetic. Observe the great difference. When the spheres are iron, the induction is near four times the force for all values of the force. When the matrix is iron, the induction is near two-fifths of the induction when the material is iron only.

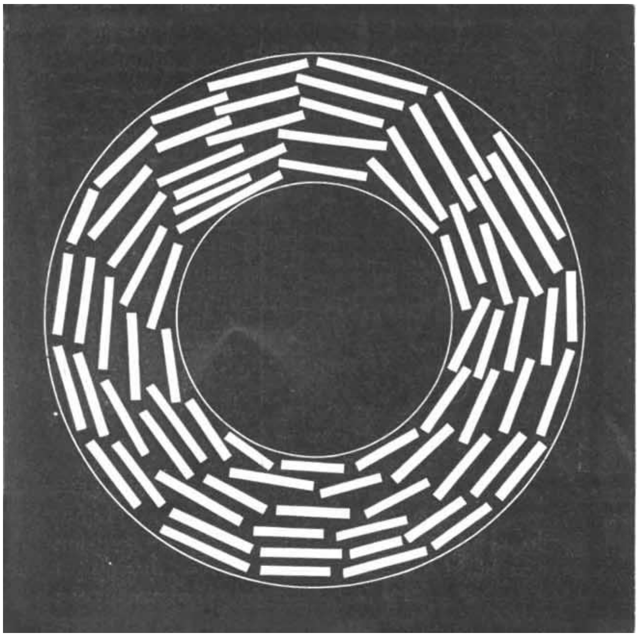
FIG. 4.

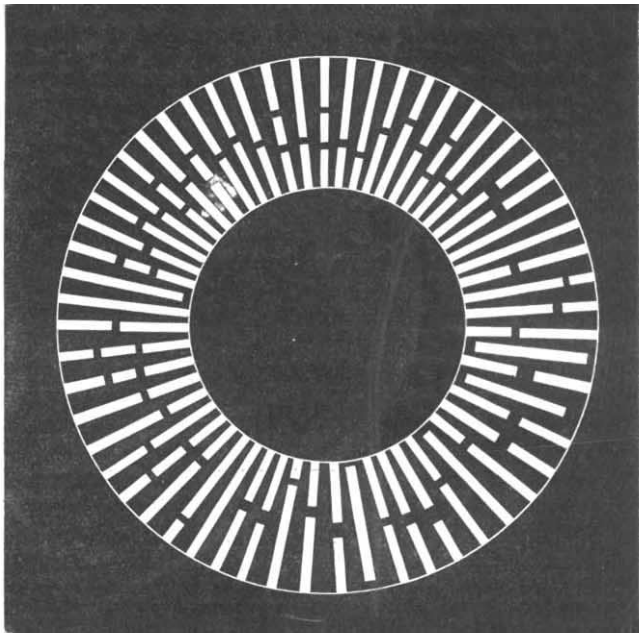
FIG. 5.

In speaking of the properties of bodies which, like manganese steel, are slightly magnetic, it may be well here to enter a caution. But little that is instructive is to be learned by testing filings, or the like, with magnets, as these show but little difference between bodies which are slightly magnetic and those which are strongly magnetic. Suppose the filings to be spheres; in the following table are given comparative values of the forces they would experience in terms of μ, if placed in a magnetic field of given value, μ having its ordinary signification—that is, being the ratio of the kick on the galvanometer when a ring is tried made of the material of the filing to the kick if the ring is made of a perfectly non-magnetic material:—

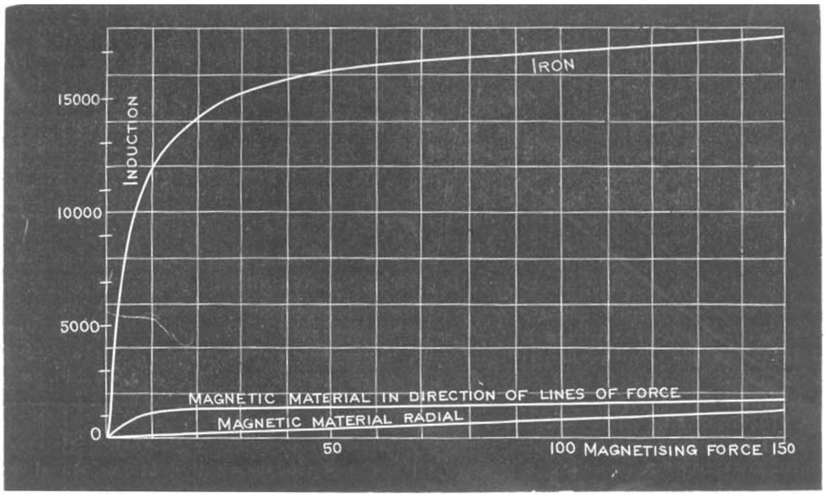

FIG. 6.

μ.	Attraction.	
1	0	Non-magnetic body.
1·47	0·18	Manganese steel with 12 per cent.
3·6	1·2	Manganese steel with 9 per cent.
5	1·5	
10	2·1	
100	2·8	
1000	2·98	

Now bodies in which μ is so small as $3{\cdot}6$ belong distinctly to the non-magnetic class; but the test with the magnet would very markedly distinguish them from manganese steel with 12 per cent of manganese. The distinction, however, between $\mu = 3{\cdot}6$ and $\mu = 1000$ is comparatively small; whereas, under the conditions of experiment, μ is much more than 1000 for most bodies of which iron is the principal constituent.

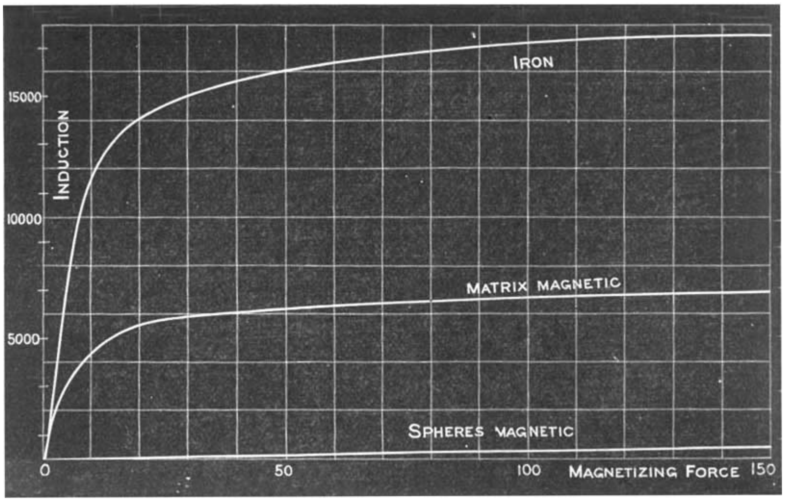

Fig. 7.

The effect of stress on the magnetic properties of iron and nickel have been studied by Sir W. Thomson. A fact interesting from a broad and general point of view is that the effects of stress are different in kind in the case of iron and nickel. In the case of iron, for small magnetizing forces in the direction of the tension, tension increases the magnetization; for large forces, diminishes it. In the case of nickel the effect is always to diminish the magnetization.

(*To be continued.*)

LORENZO RESPIGHI.

During the last forty years the Eternal City has possessed two astronomical observatories. It was at the old building, connected with the Collegio Romano, that Scheiner collected the principal materials for his famous work on the sun, called from its dedication to Prince Orsini, the Duke of Bracciano, "Rosa Ursina"; and though it is with some justice that Delambre speaks disparagingly of its contents as compared with its bulk, the observations of the solar spots show with what care they were made, and they afford the first indication of the now familiar fact that their rotation varies in duration in different heliographical latitudes, though Scheiner's idea seems to have been that it was not the same in the two solar hemispheres. But it was not until 1787 that the present observatory of the Collegio Romano was commenced, nor until 1804 that the general interest felt in the great eclipse of February 11 in that year induced Pope Pius VII. to provide G. Calandrelli with the means of furnishing it with suitable instruments. Another astronomical phenomenon, the appearance of the great comet of 1843, led his son Ignazio Calandrelli, to wish to form a new observatory on the Capitoline Hill; but it was not until five years later that Pius IX. was able, in 1848, to provide him with the means for carrying out this design. Meanwhile Calandrelli continued his observations at Bologna, ably assisted by the subject of our notice.

Lorenzo Respighi was born at Cortemaggiore, in the province of Placentia, in 1824. His first studies were made at Parma, from which town he proceeded to the University of Bologna, where he obtained high honours in the departments of mathematics and philosophy in 1847. Nominated Professor of Optics and Astronomy in 1851, he subsequently succeeded Calandrelli as Director of the Observatory. On the retirement of the latter in 1865 (followed by his death in 1866) Respighi was appointed his successor. His earliest papers were on mechanical and optical subjects; but he will be best remembered by his subsequent labours on stellar spectra, on those of the solar corona and protuberances, and on the scintillation of the stars. In 1871 he went on an expedition to Poodocottah, in Hindustan, to observe the total eclipse of December 12 in that year; an account of the observations will be found in the eclipse (41st) volume of the Memoirs of the Royal Astronomical Society, of which Respighi was elected an Associate in 1872. He formed from his observations between 1875 and 1881 a catalogue of 2534 stars in the northern hemisphere from the first to the sixth magnitude, which was published in successive numbers of the Memoirs of the Lincean Academy.

His death took place after a long illness, aggravated by the recent epidemic, on December 10 last, and the Campidoglio Observatory has thus been deprived of its second director, who has so ably and energetically conducted its operations during nearly the last quarter of a century.

W. T. Lynn.

NOTES.

On Saturday evening, at the Royal Institution, Prof. Max Müller delivered an address to inaugurate the establishment of a school for modern Oriental studies by the Imperial Institute in union with University College and King's College, London. The Prince of Wales presided, and among those present were many eminent persons, including some distinguished Orientals Prof. Müller presented with admirable force and clearness the need for a great English school for Oriental studies, and had much to tell his hearers as to work done in this direction in other countries. His account of the new Berlin seminary of